UNITED STATES PATENT APPLICATION

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for

FIXED ANGLE SWASH PLATE COMPRESSOR

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Title Of Invention

FIXED ANGLE SWASH PLATE COMPRESSOR

Field Of The Invention

[0001] The present invention relates to an apparatus for generating compressed fluid. More specifically, the invention relates to a swash plate compressor that maintains a fixed angle while minimizing the number of bearing assemblies required.

Background Of The Invention

[0002] Swash plate compressors are generally known in the art. These compressors typically employ a cylinder block with a plurality of piston channels mounted on a drive shaft. A plurality of pistons are slidably disposed in the piston channels and are coupled to a swash plate that is also mounted on the drive shaft. In accordance with the rotation of the drive shaft, the swash plate pivots, causing reciprocal motion of the pistons within the piston channels, thereby alternately creating suction and compression strokes.

[0003] These compressors employ a variety of mechanisms that utilize the rotational force of the drive shaft to make the swash plate pivot, such as an actuating assembly with a slanted surface underneath the swash plate, as disclosed in U.S. Patent No. 6,439,857 to Koelzer and assigned to the assignee of the present application, an assembly of rotating and non-rotating plates, as disclosed in U.S. Patent No. 5,626,463 to Kimura, and a rotatable cylinder block, as disclosed in U.S. Patent No. 5,394,698 to Takagi.

[0004] As the swash plate pivots, the pistons reciprocate within the piston channels of the cylinder block, alternately drawing fluid to be compressed into the channels and subsequently compressing and discharging the fluid. In this way, the rotational force of the shaft is converted into axial motion of the pistons, enabling the pistons to alternately perform the functions of suction and compression, and thus, fluid is first drawn into a piston channel and is subsequently compressed and discharged from the piston channel.

[0005] One problem with these swash plate compressors, however, is that they are typically difficult and expensive to manufacture, for several reasons. First, because the drive shaft on which the swash plate is mounted rotates, and because the swash plate is connected to pistons which are disposed in the piston channels in the cylinder block, the compressor typically requires a somewhat complex assembly to accommodate these competing interests of rotation and non-rotation. Even if an advantageous bearing assembly such as that disclosed in U.S. Patent No. 6,439,857 to Koelzer is utilized, one must still employ an actuating mechanism as disclosed therein in order for the swash plate to function properly.

[0006] Moreover, due to the nature and function of a compressor swash plate, the swash plate assembly necessarily experiences both radial and axial loads as a result of the simultaneous rotational motion of the swash plate and axial motion of the pistons. Accordingly, it is necessary for these assemblies to employ both radial bearings and thrust bearings, such as the design disclosed in U.S. Patent Application US 2001/0008607 (Richter).

[0007] What is desired, therefore, is a swash plate compressor that is inexpensive to manufacture. What is further desired is a swash plate compressor that is easy to assemble. What is also desired is a swash plate compressor that minimizes the amount of bearings required.

Summary Of The Invention

[0008] Accordingly, it is an object of the present invention to provide a swash plate compressor that is not complex.

[0009] It is a further object of the present invention to provide a swash plate compressor that does not require an actuating mechanism for the swash plate.

[0010] It is yet another object of the present invention to provide a swash plate compressor that does not require separate radial and thrust bearings.

[0011] In order to overcome the deficiencies of the prior art and to achieve at least some of the objects and advantages listed, the invention comprises a compressor including a housing, a shaft disposed in the housing, the shaft having a longitudinal axis, an inner swash plate portion attached to the shaft at a fixed angle relative to the longitudinal axis of the shaft, an outer swash plate portion coupled to the inner swash plate portion, and a bearing assembly by which the outer swash plate portion is coupled to the inner swash plate portion, wherein the bearing assembly is adapted to accommodate both the radial load and the axial load of the swash plate portions.

[0012] In another embodiment, the invention comprises a compressor including a housing, a shaft disposed in the housing, the shaft having a longitudinal axis, a swash plate coupled to the shaft at a fixed angle relative to the longitudinal axis of the shaft, and a bearing assembly by which the swash plate is coupled to the shaft, wherein the bearing assembly is adapted to accommodate both the radial load and the axial load of the swash plate.

[0013] In yet another embodiment, the invention comprises a compressor including a housing having at least one piston channel, a shaft disposed in the housing, a swash plate coupled to the shaft, at least one piston disposed in the at least one piston channel and movable therein, wherein the swash plate is coupled to the at least one piston and inclined at an angle relative to the direction of motion thereof, and a bearing assembly by which the swash plate is coupled to the shaft, such that the angle at which the swash plate is inclined relative to the direction of motion of the at least one piston remains fixed as the shaft rotates, wherein the bearing assembly is adapted to accommodate both the radial load and the axial load of the swash plate.

[0014] In still another embodiment, the invention comprises a compressor including a housing, a shaft disposed in the housing, the shaft having a longitudinal axis, an inner swash plate portion attached to the shaft at a fixed angle relative to the longitudinal axis of the shaft, an outer swash plate portion coupled to the inner swash plate portion, and an angular contact bearing by which the outer swash plate portion is coupled to the inner swash plate portion.

[0015] In yet another embodiment, the invention comprises a compressor including a housing, a shaft disposed in the housing, the shaft having a longitudinal axis, a swash plate coupled to the shaft at a fixed angle relative to the longitudinal axis of the shaft, and an angular contact bearing by which the swash plate is coupled to the shaft.

Brief Description Of The Drawings

[0016] Figure 1 is an isometric view of a swash plate compressor in accordance with the invention.

[0017] Figure 2 is a cross-sectional side view of the compressor of Figure 1.

[0018] Figure 3 is a cross-sectional side view of another embodiment of the compressor of Figure 1.

[0019] Figure 4 is an isometric view of the swash plate assembly of the compressor of Figure 3.

[0020] Figure 5 is another cut-away, cross-sectional side view of one embodiment of the shaft and swash plate of the compressor of Figure 1.

[0021] Figure 6a is a partial cross-sectional, isometric view of a standard radial bearing.

[0022] Figure 6b is a partial cross-sectional, isometric view of an angular contact bearing of the swash plate of the compressor of Figure 1.

[0023] Figure 7 is an exposed side view of the ball bearing of Figure 6b.

[0024] Figure 8 is a partial cross-sectional, isometric view of a tapered roller bearing used in some embodiments of the swash plate of the compressor of Figure 1.

[0025] Figure 9 is a cross-sectional side view of a four point contact bearing used in some embodiments of the swash plate of the compressor of Figure 1.

[0026] Figure 10a is a cross-sectional side view of a tandem duplex-bearing used in some embodiments of the swash plate of the compressor of Figure 1.

[0027] Figure 10b is a cross-sectional side view of a face-to-face duplex-bearing used in some embodiments of the swash plate of the compressor of Figure 1.

[0028] Figure 10c is a cross-sectional side view of a back-to-back duplex-bearing used in some embodiments of the swash plate of the compressor of Figure 1.

[0029] Figure 10d is a cross-sectional side view of a double row angular contact bearing used in some embodiments of the swash plate of the compressor of Figure 1.

[0030] Figure 10e is a cross-sectional side view of a shielded type of the double row angular contact bearing of Figure 10d.

[0031] Figure 10f is a cross-sectional side view of a sealed type of the double row angular contact bearing of Figure 10d.

Detailed Description Of The Drawings

[0032] The basic components of one embodiment of a swash plate compressor 10 in accordance with the invention are illustrated in Figure 1. As used in the description, the terms "top," "bottom," "above," "below," "over," "under," "on top," "underneath," "up," "down," "upper," "lower," "front," "rear," "forward" and "back" refer to the objects referenced when in the orientation illustrated in the drawings, which orientation is not necessary for achieving the objects of the invention.

[0033] Typically, the compressor 10 includes a main body 12, a rear mounting cover 14, and a front mounting flange 16. When in use, the compressor 10 is installed on a vehicle, such as an over-the-road truck, and generates compressed air for the vehicle's pressure system, which typically

includes a tank (not shown) that supplies the compressed air to various accessories, such as, for example, the brake system. This production of the compressed air begins by receiving air, which may or may not be delivered from a turbocharger (not shown), in response to a reduction of the air pressure in the air system to or below a reference pressure. Though, in the embodiment described herein, the fluid is air, in certain other embodiments, the fluid may comprises any of various gases, liquids, or mixtures thereof.

[0034] The basic components of one embodiment of the main body 12 of the compressor 10 are illustrated in Figure 2. The main body 12 includes a swash plate housing 20 defining a swash plate chamber 22 therein, and a stationary cylinder block 26 mounted to the housing 20. A drive shaft 40 extends through both the housing 20 and the cylinder block 26 and is rotatable therein. A swash plate 24 is disposed in the swash plate chamber 22 and mounted on the shaft 40. A plurality of pistons 30 are coupled to the swash plate 24, and the cylinder block 26 has a plurality of piston channels 32 that receive the pistons 30. The pistons 30 are reciprocally displaceable within the piston channels 32 in order to produce suction and compression strokes.

[0035] Each piston 30 has a face 31 for contacting the air to be compressed. Accordingly, a compression chamber 34 is formed from the space in the piston channel 32 to which the piston face 31 is exposed. The compression chamber 34, which is in fluid communication with the air system, both receives air to be compressed and discharges air after compressing it. Accordingly, the air pressure in the compression chamber 34 corresponds to the air pressure in the air system, thereby ensuring a state of pressure equilibrium for the compressor 10, as is further explained below.

[0036] Typically, the main body 12 of the compressor 10 further includes a compressor head 18 mounted adjacent to the cylinder block 26.

The compressor head has an inlet channel 80 and an outlet channel 82 that are both in communication with the compression chambers 34. In order to regulate the entry of uncompressed air from the inlet channel 80, and the discharge of compressed air to the outlet channel 82, and to prevent the back-feeding of this air, the compressor 10 is typically provided with a plurality of inlet and outlet valves 84, 85. The valves 84, 85, which are often one-way reed or poppet valves, allow air to flow along a path from a high-pressure area to a low-pressure area, and are typically part of the compressor head 18, or are created using valve plates 86, 87 disposed between the compressor head 18 and the cylinder block 26.

[0037] In some embodiments, the compressor head 18 is provided with inlet and outlet ports, 90, 92, which are in fluid communication with the inlet and outlet channels 80, 82, respectively. Accordingly, air may be drawn in through the inlet port 90, into the inlet channel 80 and past the inlet valves 84, to the compression chambers 34 where it can be compressed. Similarly, once air is compressed and discharged from the compression chambers 34 through the outlet valves 85 and into the outlet channel 82, the air may be directed to the air system via the outlet port 92.

[0038] In other embodiments, however, as shown in Figure 3, the swash plate housing 20 is provided with an inlet port 91, thereby eliminating the need for an inlet port in the compressor head 18. In these embodiments, air enters the swash plate chamber 22, cooling any bearings that may be found therein, and is communicated to the inlet channel 80 via a passageway 93.

[0039] In certain advantageous embodiments, as illustrated in Figures 3-4, the swash plate 24 has an outer part 42 and inner part 44, wherein the outer part 42 is coupled to the inner part 44 via a bearing 46. The inner part 44 is mounted on the shaft 40 with a series of pins 48, such that the inner part

44 rotates with the shaft 40. As the shaft 40 rotates, the bearing 46 permits the outer part 42 of the swash plate 24 to be restrained as the inner part 44 rotates with the shaft 40. Accordingly, the outer part 42, the pistons 30, and the cylinder block 26 can all be non-rotating. With this arrangement, the shaft 40 can continue to rotate even when the compressor 10 is not compressing air and the pistons 30 are idle. As a consequence, accessories coupled to the shaft 40, such as, for example, a fuel pump (not shown), continue to function.

[0040] In certain embodiments, in order to prevent the outer part 42 from rotating, the swash plate 24 receives a radially extending stopper 49 that engages an axial groove of the housing 20, as shown in Figure 4. In other embodiments, as shown in Figure 2, a gimbal arm 100 may be used to prevent the outer part 42 from rotating.

[0041] Refering again to Figures 2-3, in order to facilitate the reciprocal motion of the pistons 30 within the piston channels 32, the entire swash plate 24 remains inclined at a fixed angle 140 with respect to the longitudinal axis 39 of the shaft 40. Because the angle 140 is fixed, the inclined plane of the swash plate 24 rotates as the shaft 40 rotates. In this way, the rotational motion of swash plate 24 about the shaft 40 causes reciprocal displacement of the pistons 30 parallel to the axis 39 of the shaft 40.

[0042] To permit this reciprocal displacement, the pistons 30 are coupled to the swash plate 24 via a bearing. In the embodiment described herein, the outer part 42 of the swash plate 24 includes a plurality of ball links, each of which is comprised of a swash plate rod 52 and a ball element 54. In certain embodiments, the rods 52, which are typically spaced angularly equidistantly from one another along an outer periphery of the swash plate 24 and extend radially therefrom, are bolts having a thread on one end, which is screwed into the swash plate 24, and a nut 58 on the opposite end.

[0043] The ball element 54 has a spherical outer surface for slidably engaging a flange 62 of a piston rod 60, which extends parallel to the rotating shaft 40. Accordingly, as the plane of inclination of the swash plate 24 rotates, and the position of the flange 62 changes relative to the plane perpendicular to the longitudinal axis 39 of the drive shaft 40, the cooperating surfaces of the ball element 54 and flange 62 slide relative to one another. Such relative displacement allows the piston rod 60 and ball element 54 to move axially together, while the ball element 54 rotates within the flange 62 in response to the rotating angle of inclination of the swash plate 24. Though the cooperating surfaces of the ball element 54 and flange 62 are depicted as annular, in certain embodiments, other shapes that move synchronously while being angularly displaced relative to one another may be used. Alternatively, in other embodiments, the bearing by which the pistons 30 are coupled to the swash plate 24 may take other forms.

[0044] As explained above, in certain advantageous embodiments, and outer swash plate part 42 is coupled to an inner swash plate part 44 via a bearing 46, and the inner swash plate part 44, in turn, is attached to the shaft 40 at an angle 140 relative to the longitudinal axis 39 of the shaft 40 that remains fixed. Accordingly, while the bearing 46 enables the outer part 42 to not rotate along with inner part 44 and shaft 40, the angle of inclination of the outer part 42 will rotate along with the angle of inclination of the inner part 44. In this way, the pistons 30 are displaced back and forth within the piston channels 32, thereby generating suction and compression strokes.

[0045] For example, the inner part 44 may be connected to the shaft 40 by a plurality of fasteners, such as pins 48, such that the inner part 44 remains at a fixed angle with respect to the longitudinal axis 39 of the shaft 40. In other embodiments, the inner part 44 may be otherwise fixedly attached to the shaft 40, such as by welding the inner part 44 to the shaft 40,

or by manufacturing the shaft 40 such that the inner part 44 is integrally formed therewith.

[0046] In other advantageous embodiments, as illustrated in Figure 5, the swash plate 24 may consist of a single, non-rotating part 45 that is directly coupled to a shaft 41 in such a way that it does not rotate with the shaft 41. This may be accomplished, for example, by providing a shaft 40 having a race 43 integrally formed therein, and by employing a bearing assembly such as bearing 46.

[0047] In order to eliminate the need for a separate thrust bearing, the bearing 46 is a bearing adapted to accommodate not only the radial load resulting from the rotation of the shaft 40 relative to at least a portion of the swash plate 24, but also the axial load resulting from the sliding motion of the pistons 30 within the piston channels 32. In certain advantageous embodiments, this bearing comprises an angular contact bearing. As can be seen by comparing Figure 6a (which depicts a standard radial bearing) with Figure 6b (which depicts an angular contact bearing), an angular contact bearing, unlike a standard radial bearing, allows the ball 110 to ride high on the edge of one of the raceways.

[0048] As illustrated in Figures 6B-7, this is accomplished by using raceways where one of the shoulders 112 is higher than the other shoulder 114, the higher shoulder 112 of the first raceway 120 being located at the opposite end from the higher shoulder 116 of the second raceway 122. As a result, instead of the ball 110 contacting the raceway 120 at an angle directly perpendicular to the longitudinal axis 39 of the shaft 40, the ball 110 will contact the raceway 120 at an angle 126, thereby enabling the bearing 46 to absorb more axial load. This angle of contact 126 is typically 15, 30, or 40 degrees from the normal angle of contact of a standard radial bearing, but does not necessarily have to be one of these specific angles.

[0049] In other embodiments, however, the bearing 46 may comprise any other bearing adapted to accommodate both the axial and radial loads of the compressor 10. For example, as illustrated in Figure 8, the bearing 46 may comprise a tapered roller bearing. In other embodiments, where just a little more axial load accommodation is needed, a four point contact bearing, as shown in Figure 9, may be used.

[0050] In certain advantageous embodiments, the bearing assembly contains multiple angular contact bearings side by side, commonly referred to as a duplex bearing. For example, in some embodiments, the bearing assembly may comprise a tandem duplex bearing, as shown in Figure 10a. In these embodiments, two angular contact bearings that are facing the same direction are positioned adjacent each other in order to increase the level of axial load that the bearing assembly is able to accommodate.

[0051] In other embodiments where the bearing assembly includes a duplex bearing—such as those where axial loads exist in two directions—two angular contact bearings may be positioned adjacent each other such the bearings are facing in opposite directions. These arrangements serve to offset opposing axial loads, and would be useful, for example, in double-acting or two-step piston compressors. In certain embodiments, as shown in Figure 10b, a face-to-face duplex bearing is employed, which allows for a larger misalignment angle. In other embodiments, as shown in Figure 10c, a back-to-back duplex bearing is employed, which provides greater rigidity.

[0052] In some embodiments, a double row angular contact bearing is employed, as shown in Figure 10d. In these embodiments, two rows of angular contact bearings are arranged with shoulders positioned similar to that of a back-to-back duplex bearing, but the inner and outer rings 130, 132 are each a single piece that spans both rows of balls.

[0053] In some of these embodiments, the bearings are shielded, as illustrated in Figure 10e. In these bearings, shields 134, which, in some cases, are made of steel, are placed at either end of the bearing in order to keep foreign materials from entering the bearing. In other embodiments, the bearings are sealed, as illustrated in Figure 10f. In these embodiments, seals 136 are placed at either end of the bearing in order to both keep out foreign materials and keep in any grease that is used in the bearing.

[0054] It should be understood that the foregoing is illustrative and not limiting, and that obvious modifications may be made by those skilled in the art without departing from the spirit of the invention. Accordingly, reference should be made primarily to the accompanying claims, rather than the foregoing specification, to determine the scope of the invention.